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(12) **United States Patent**
Foote et al.

(10) **Patent No.: US 8,314,008 B2**
(45) **Date of Patent: Nov. 20, 2012**

(54) METHOD OF MOUNTING MEMS INTEGRATED CIRCUITS DIRECTLY FROM WAFER FILM FRAME

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(73) Assignee: **Silverbrook Research Pty Ltd**, Balmain, New South Wales (AU)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **13/225,474**

(22) Filed: **Sep. 4, 2011**

(65) **Prior Publication Data**

US 2011/0318854 A1 Dec. 29, 2011

Related U.S. Application Data

(63) Continuation of application No. 12/711,256, filed on Feb. 24, 2010, now Pat. No. 8,030,175, which is a continuation of application No. 11/766,052, filed on Jun. 20, 2007, now Pat. No. 7,678,667.

(51) **Int. Cl.**
H01L 21/30 (2006.01)
H01L 21/46 (2006.01)

(52) **U.S. Cl.** **438/455**; 438/21; 438/25; 438/26; 438/51; 438/55; 257/E21.499

(58) **Field of Classification Search** 438/12–51; 257/E21.002, E21.499, E21.502
See application file for complete search history.

(56) **References Cited**

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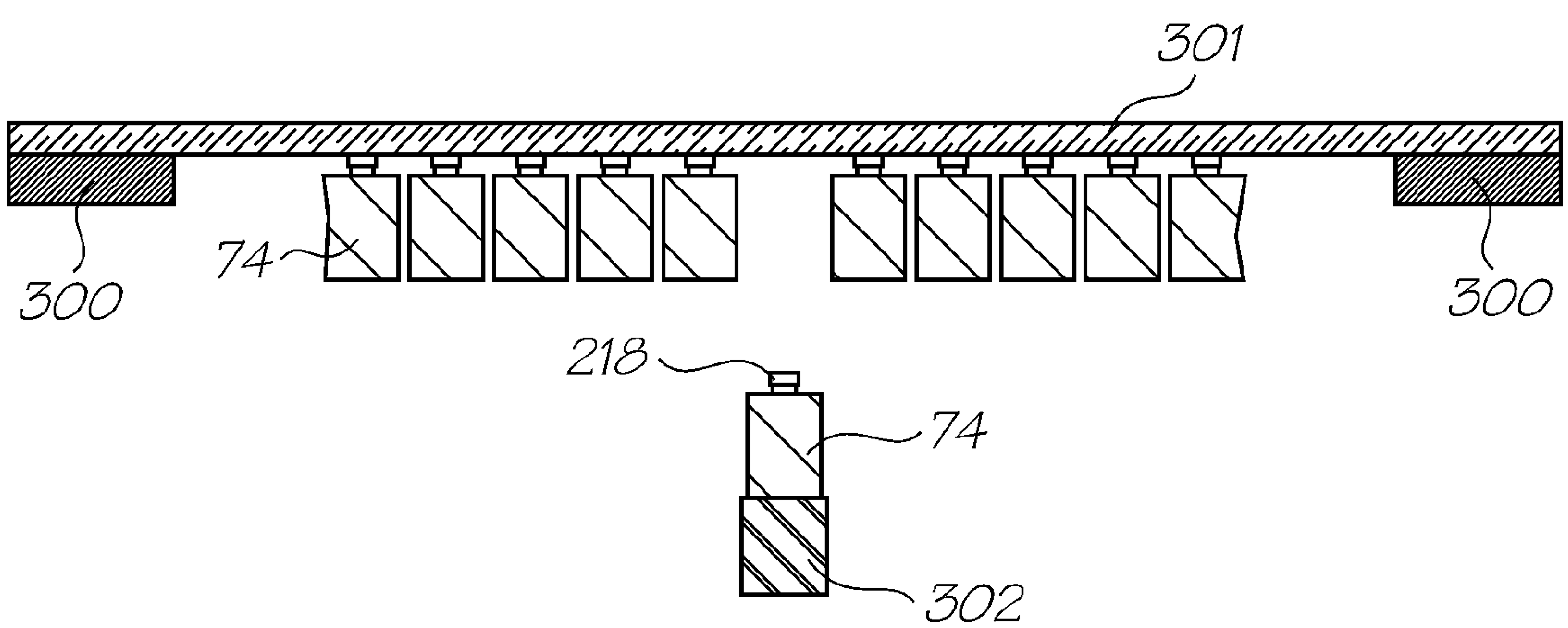
Primary Examiner — Charles Garber
Assistant Examiner — Abdulfattah Mustapha

(57) **ABSTRACT**

A method mounting a MEMS integrated circuit on a substrate. The method includes the steps of: (a) providing a film frame tape supported by a wafer film frame, the film frame tape having the plurality of MEMS integrated circuits releasably attached via respective frontsides to the film frame tape; (b) treating a backside surface oxide layer of each MEMS integrated circuit with liquid ammonia; (c) positioning a substrate at the backside of one of said MEMS integrated circuits; (d) positioning a bonding tool on a zone of the film frame tape aligned with the MEMS integrated circuit; and (e) applying a bonding force from the bonding tool so as to bond the backside of the MEMS integrated circuit to the substrate.

7 Claims, 11 Drawing Sheets



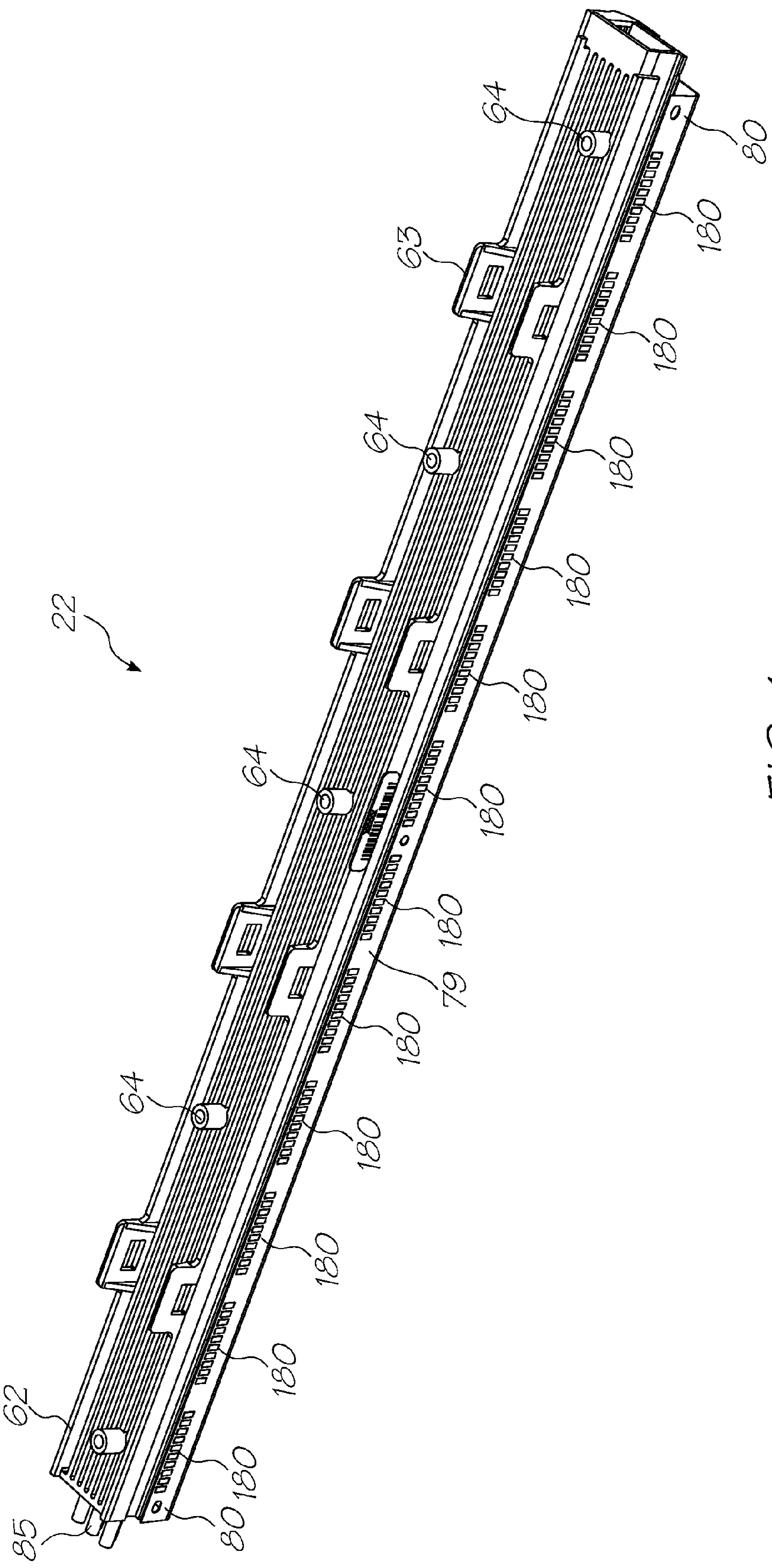

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FIG. 1

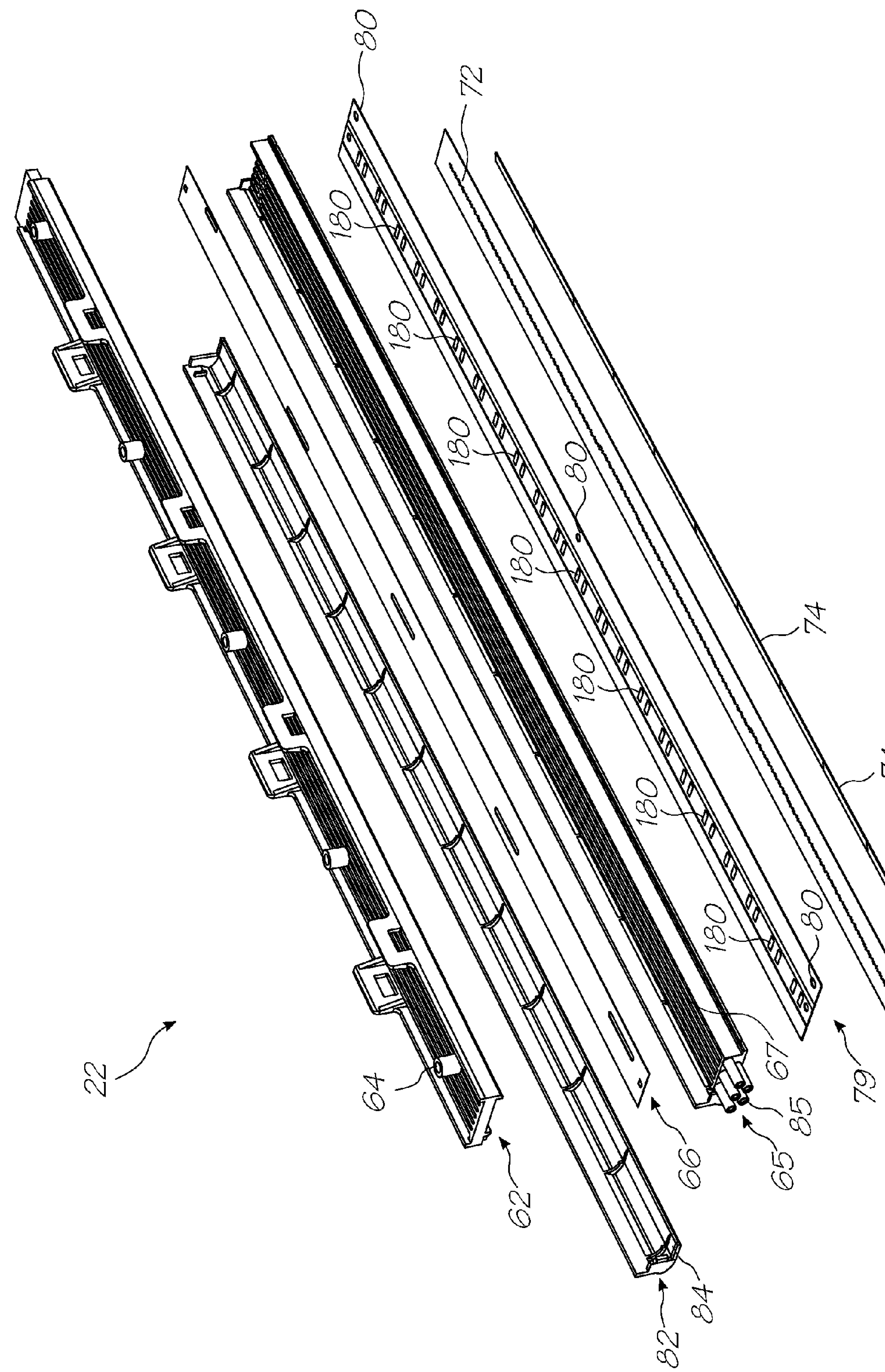
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FIG. 2

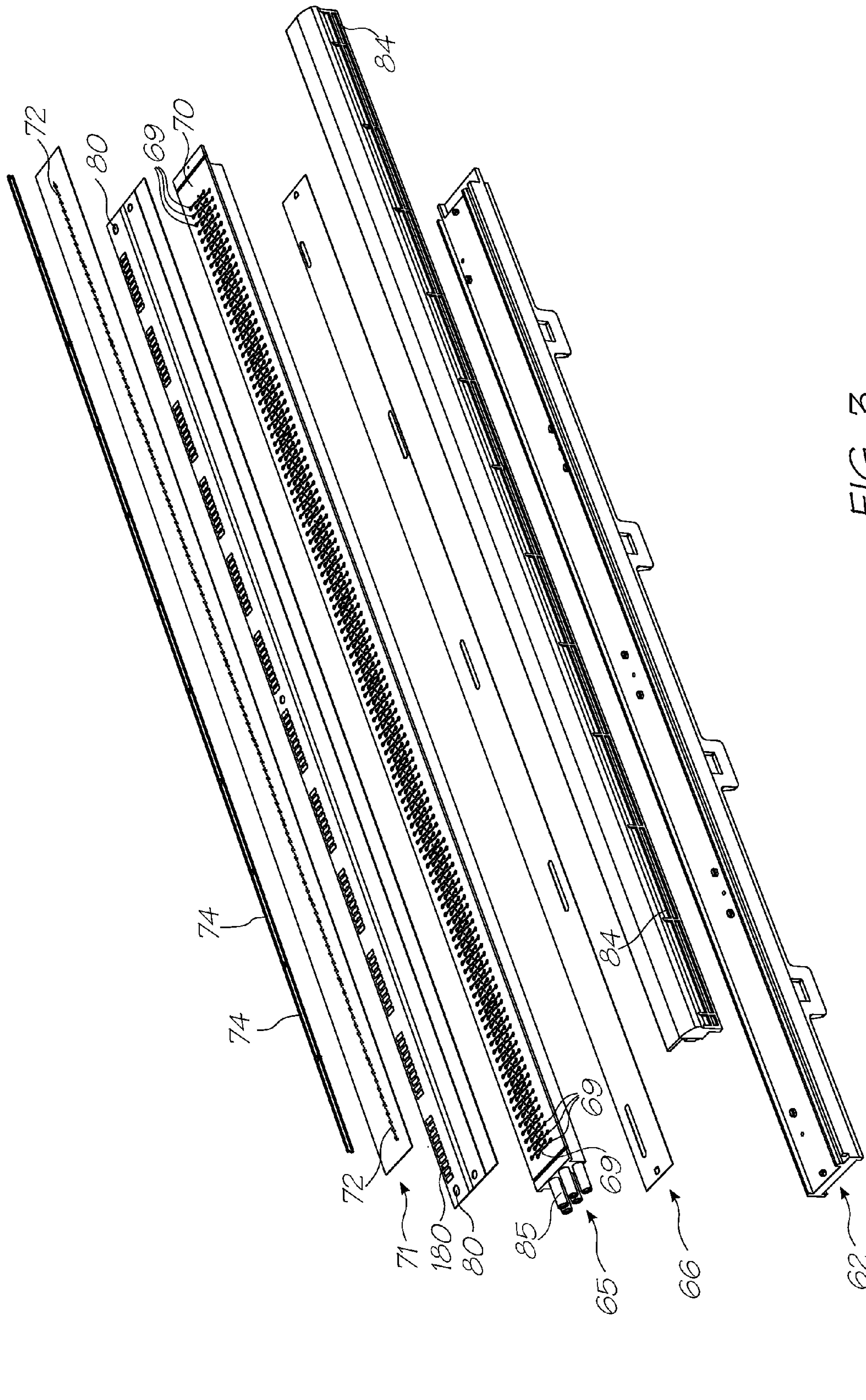

FIG. 3

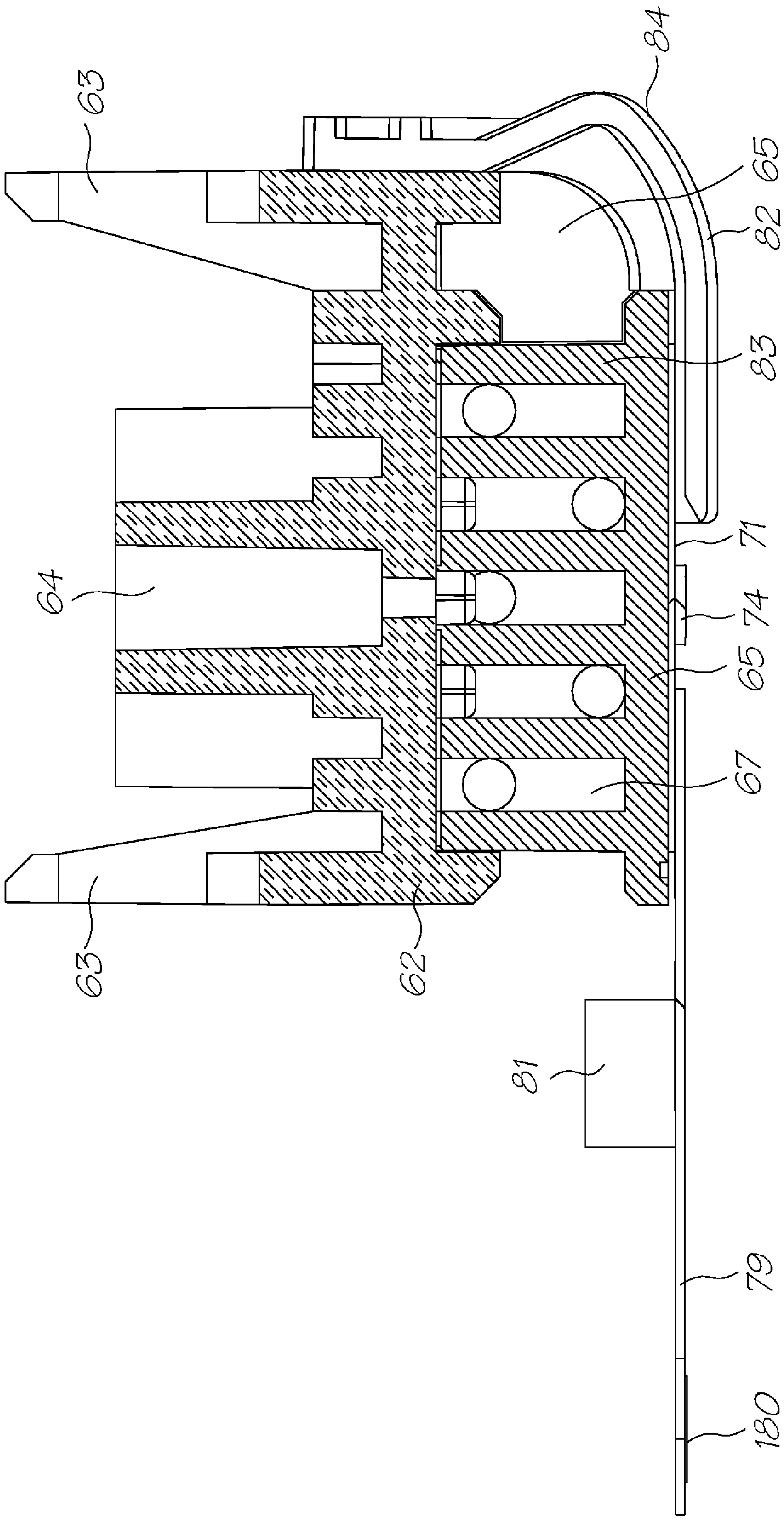

FIG. 4

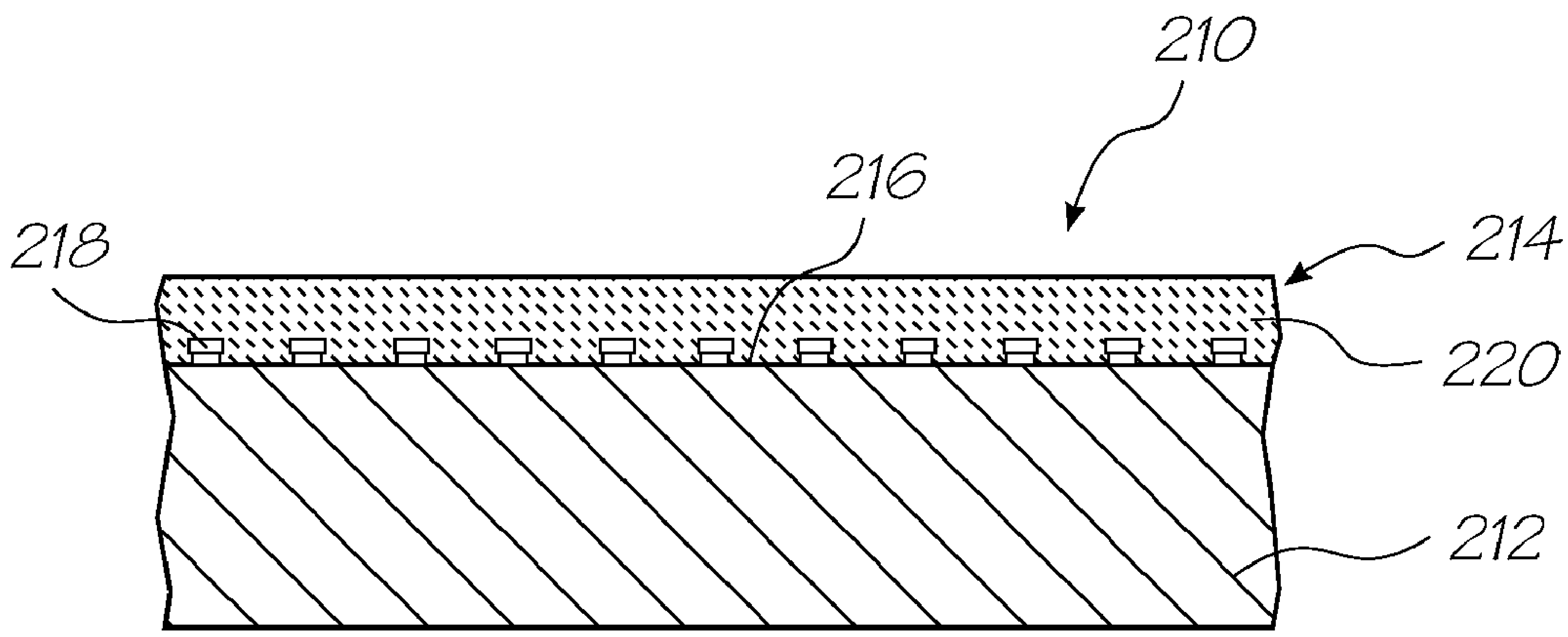

FIG. 5

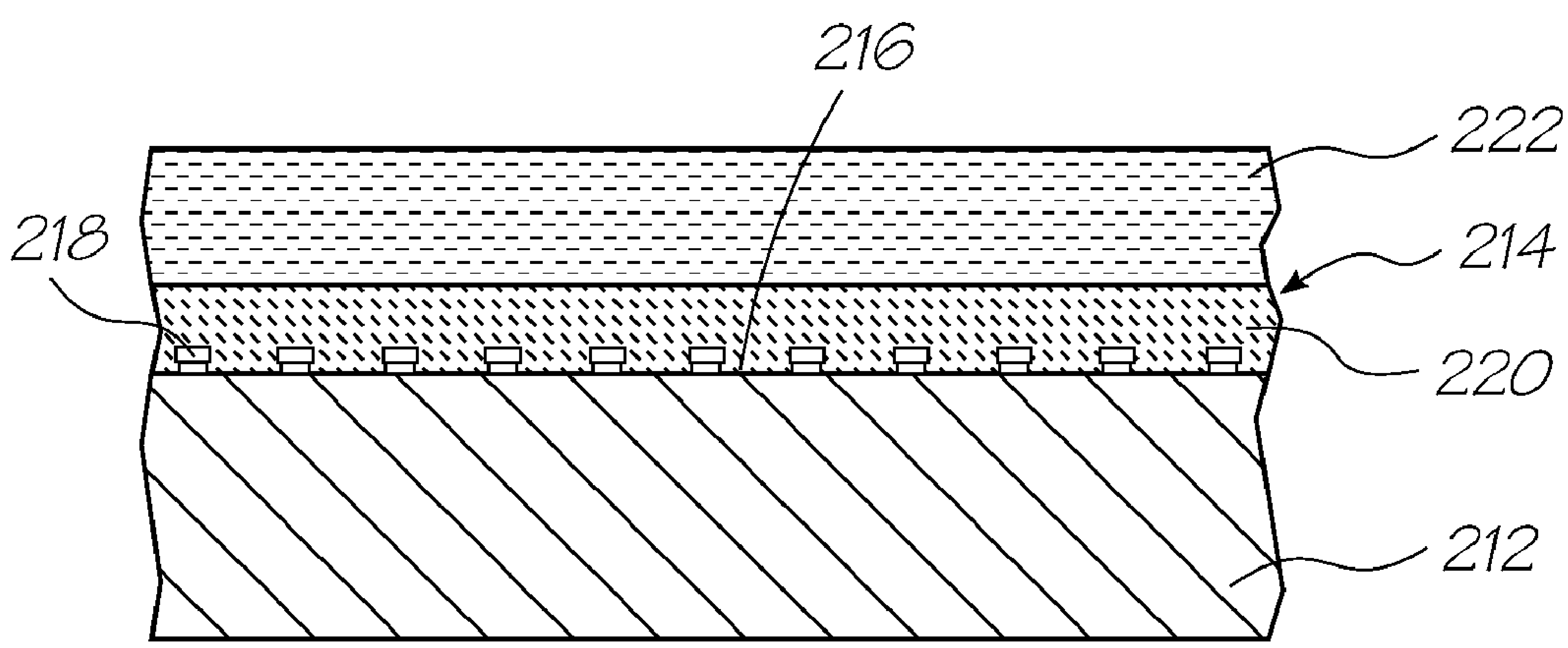

FIG. 6

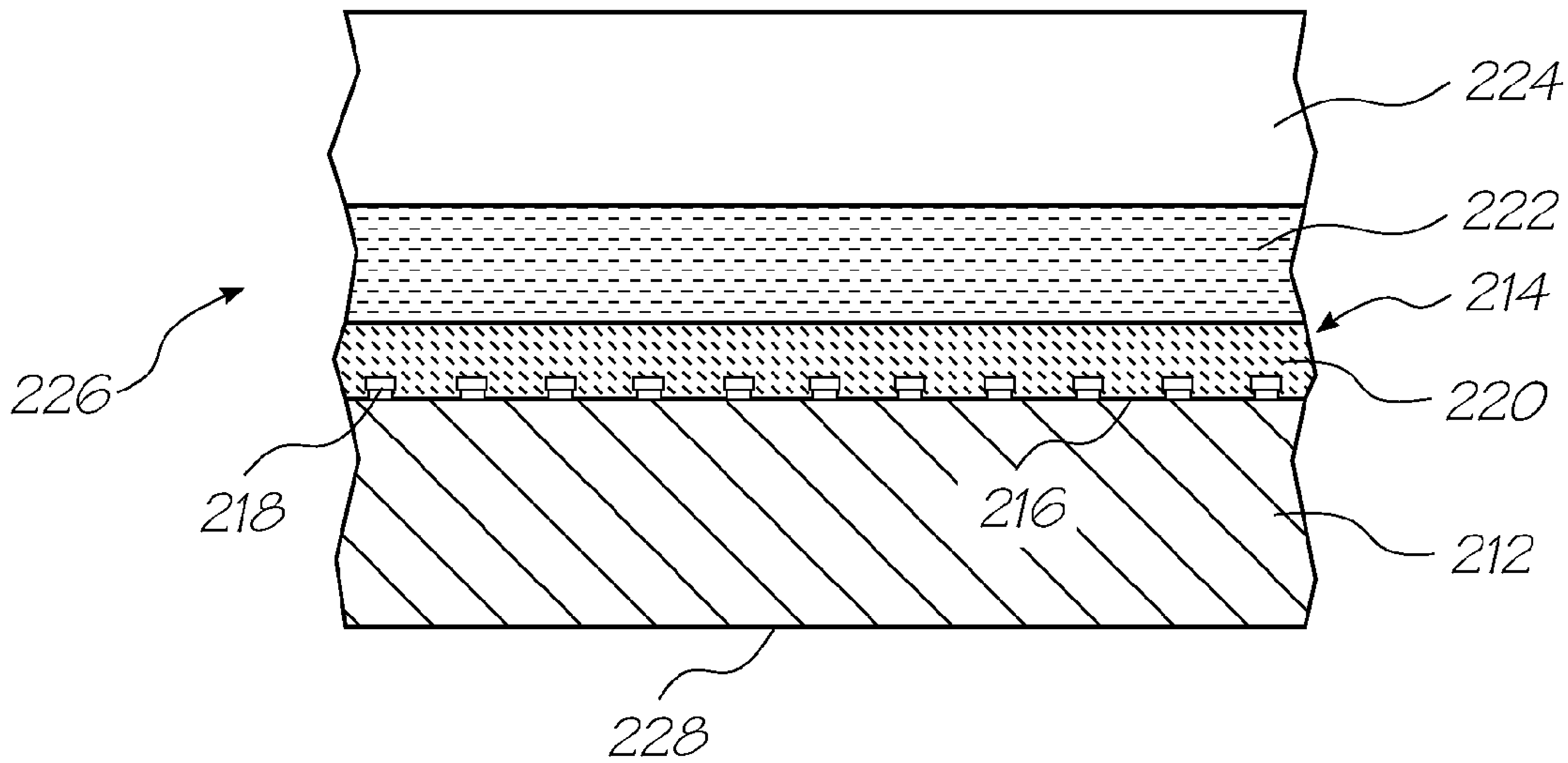
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FIG. 7

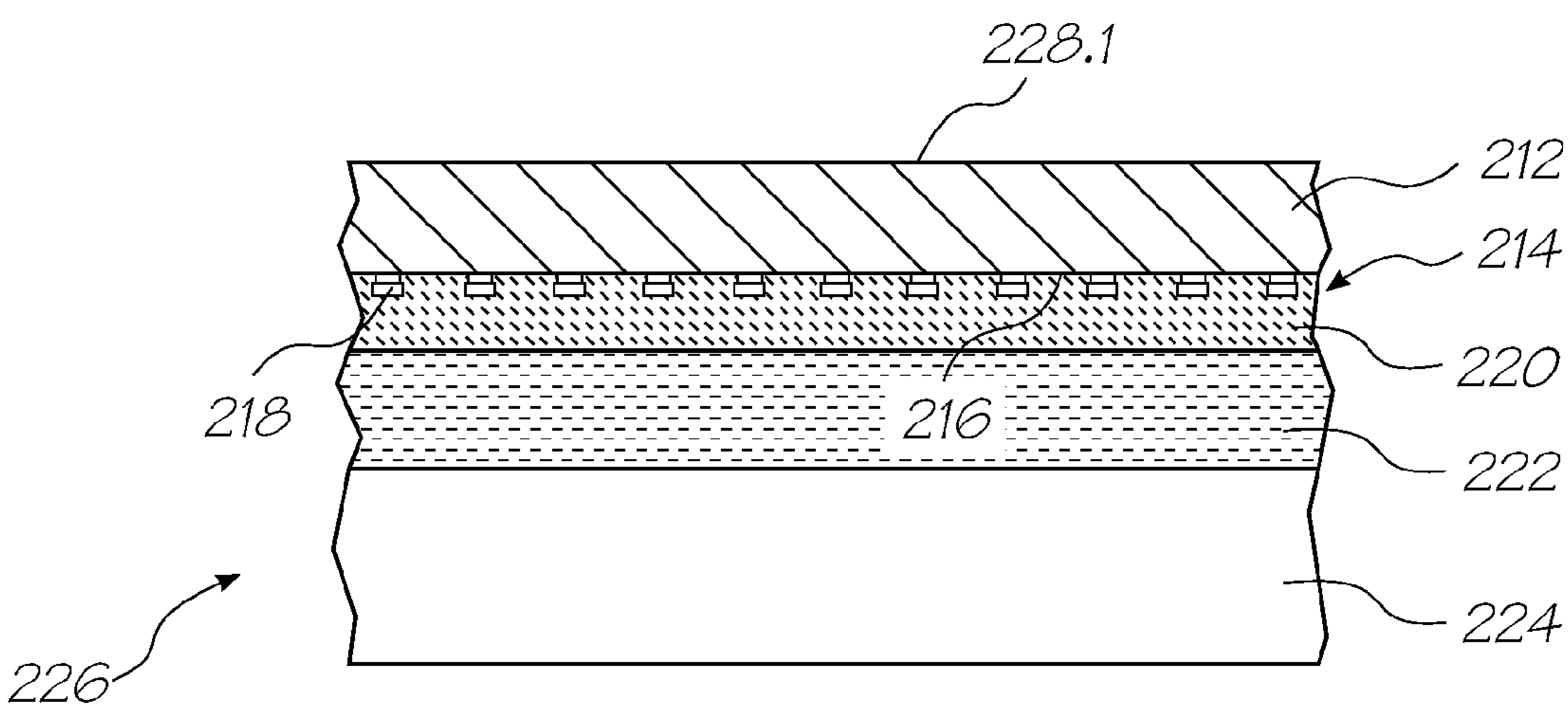
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FIG. 8

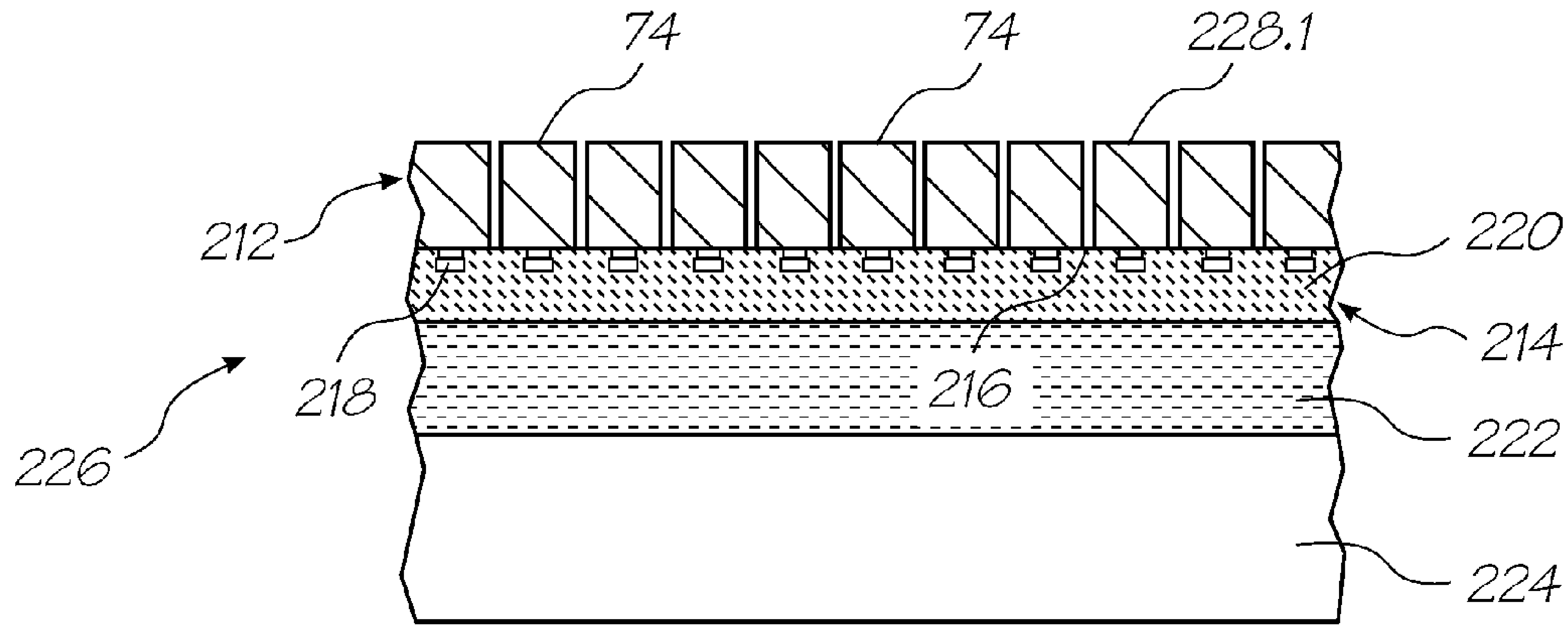
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FIG. 9

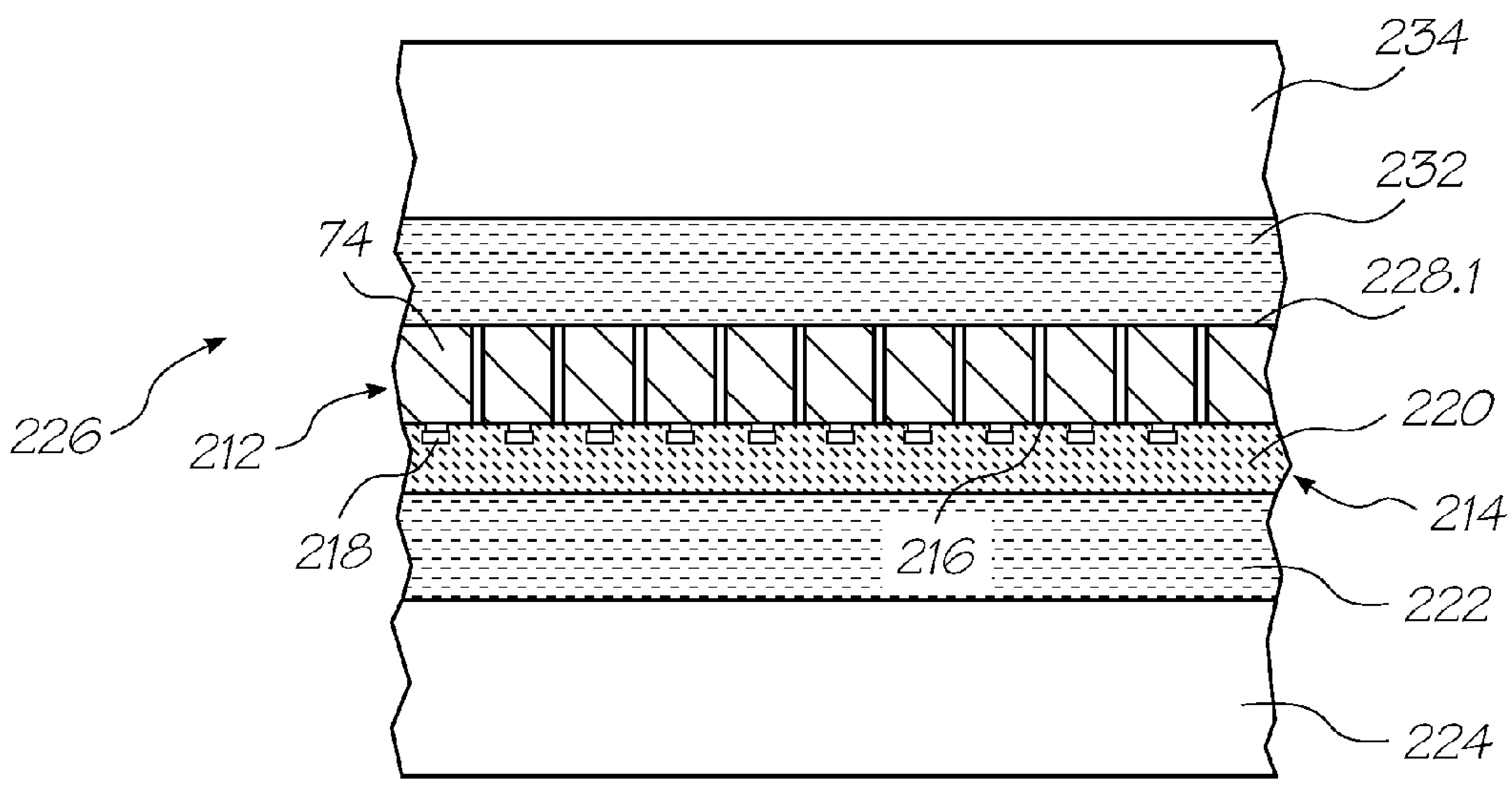
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FIG. 10

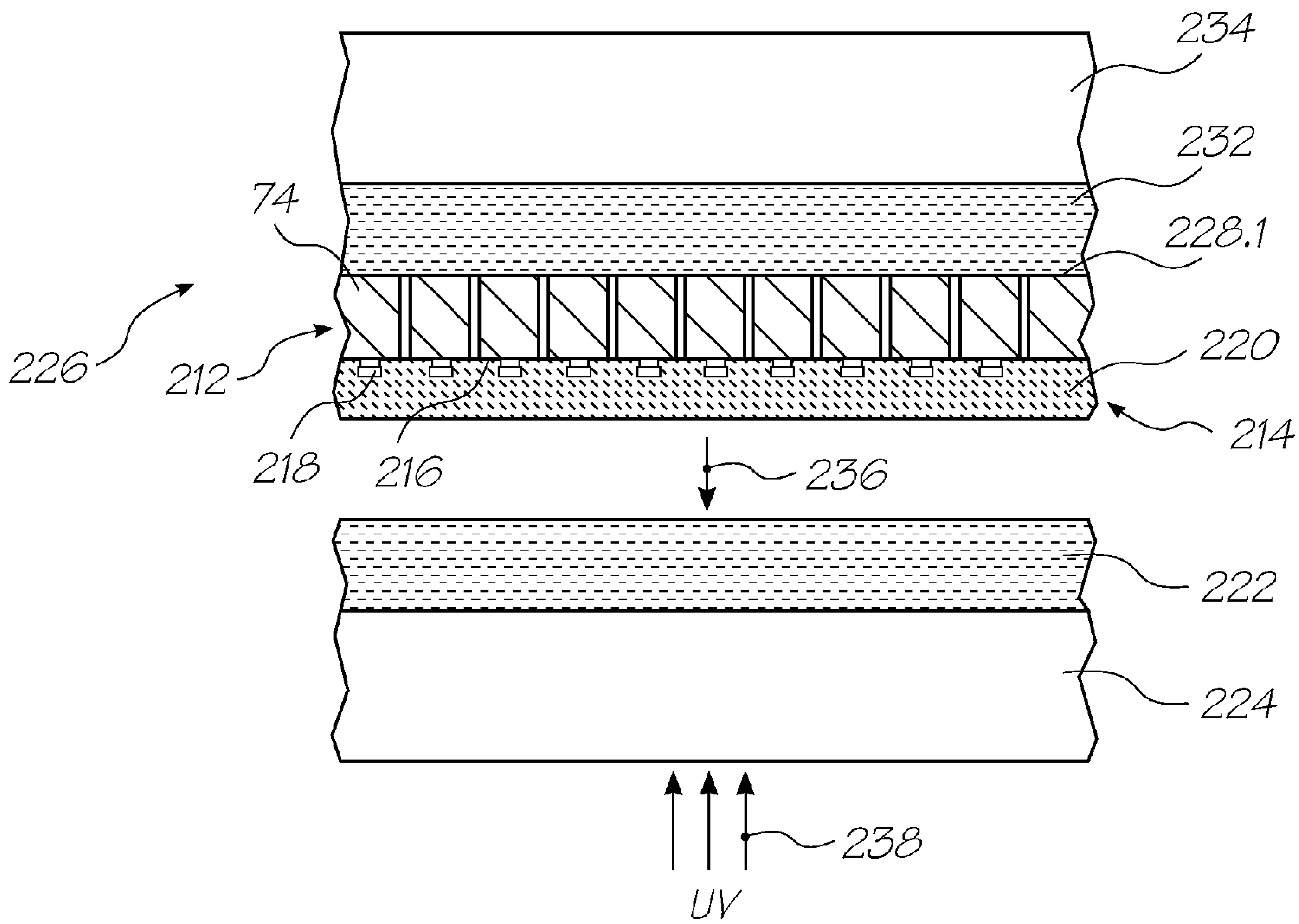
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FIG. 11

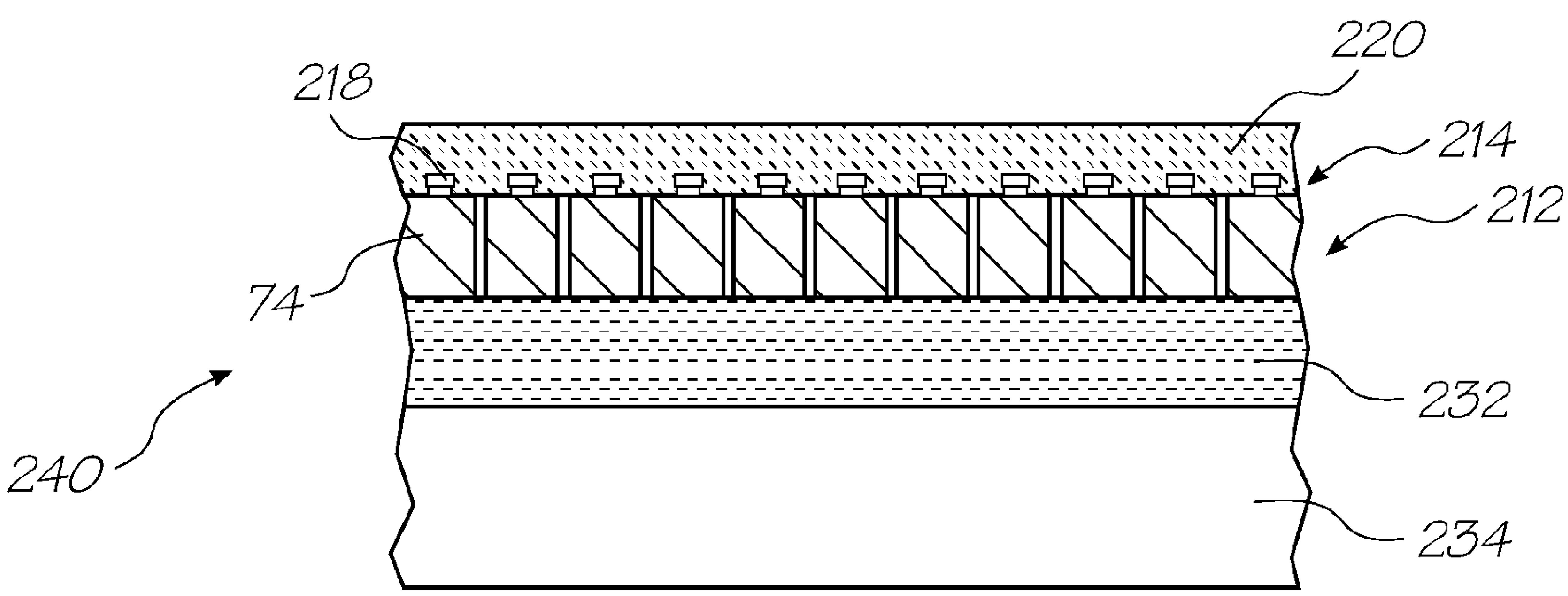
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FIG. 12

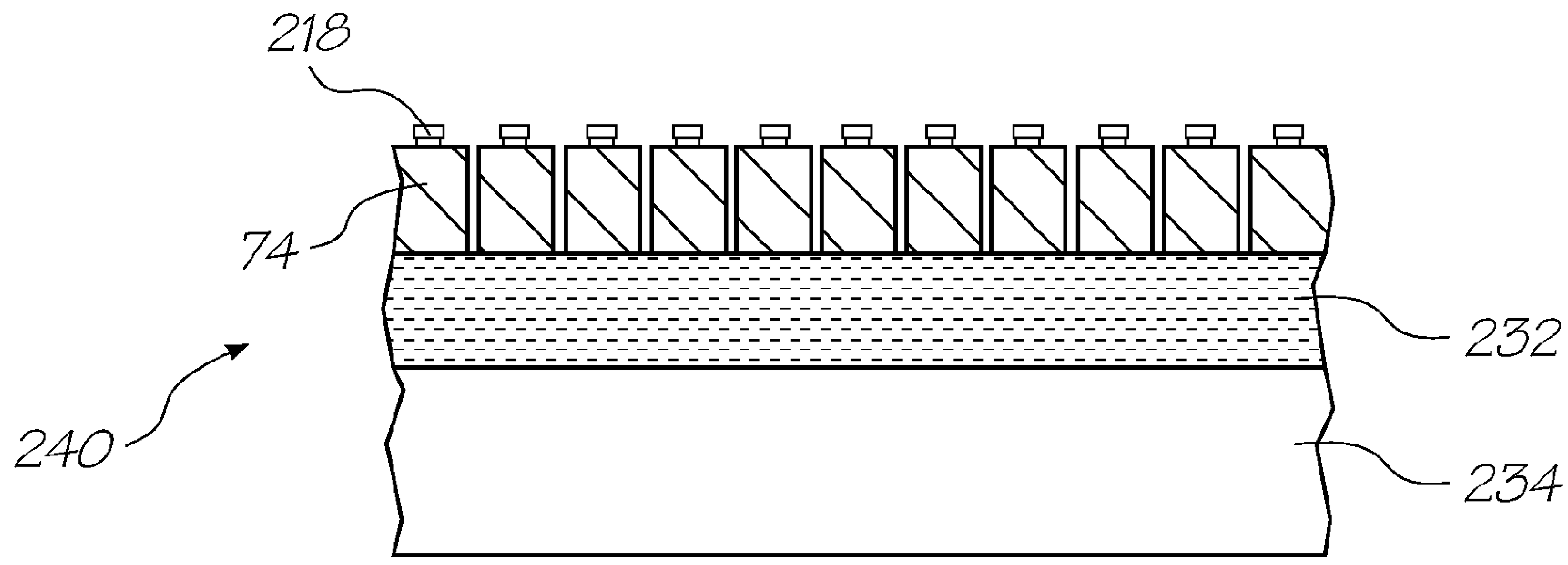

FIG. 13

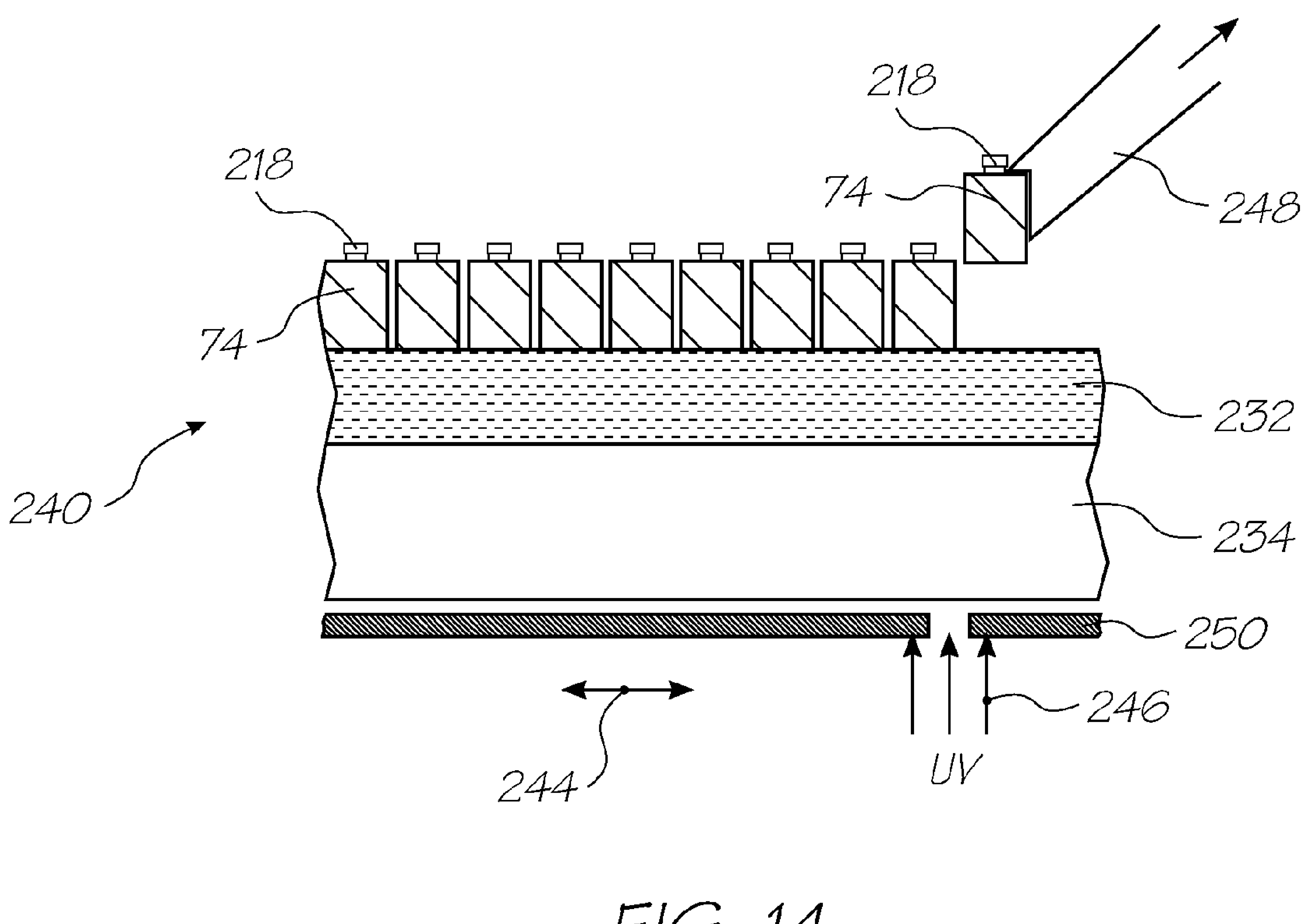

FIG. 14

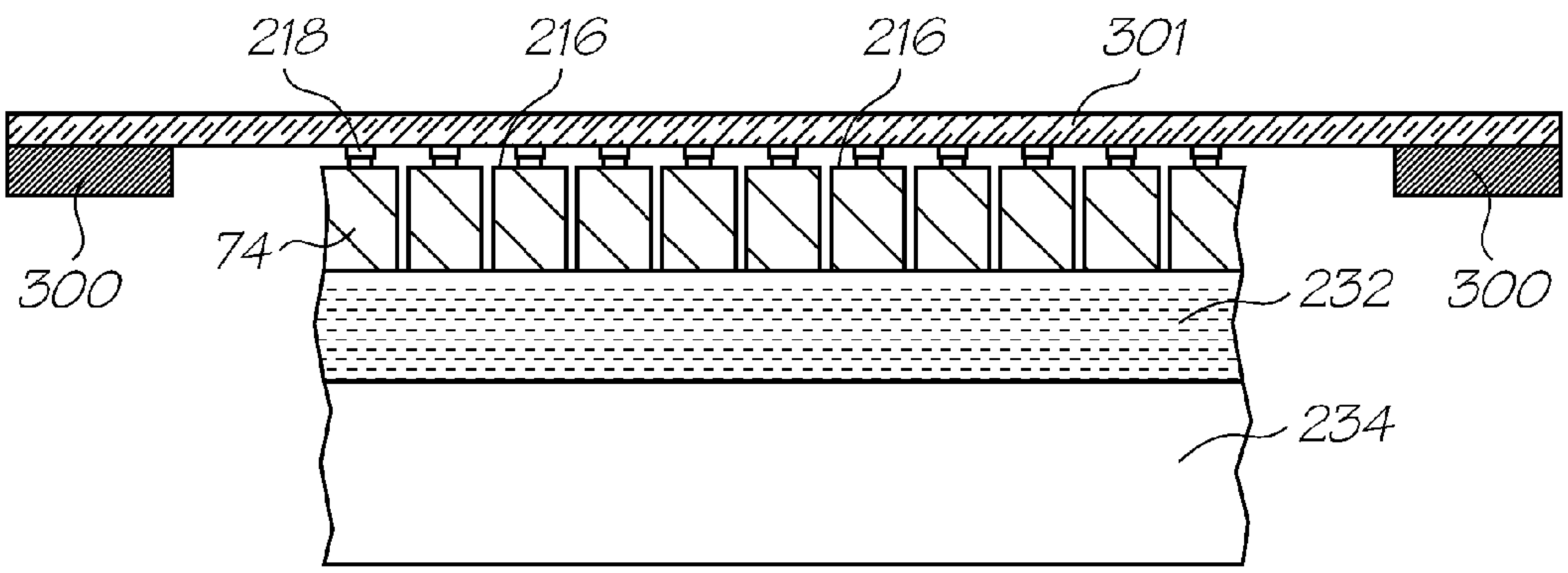
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FIG. 15

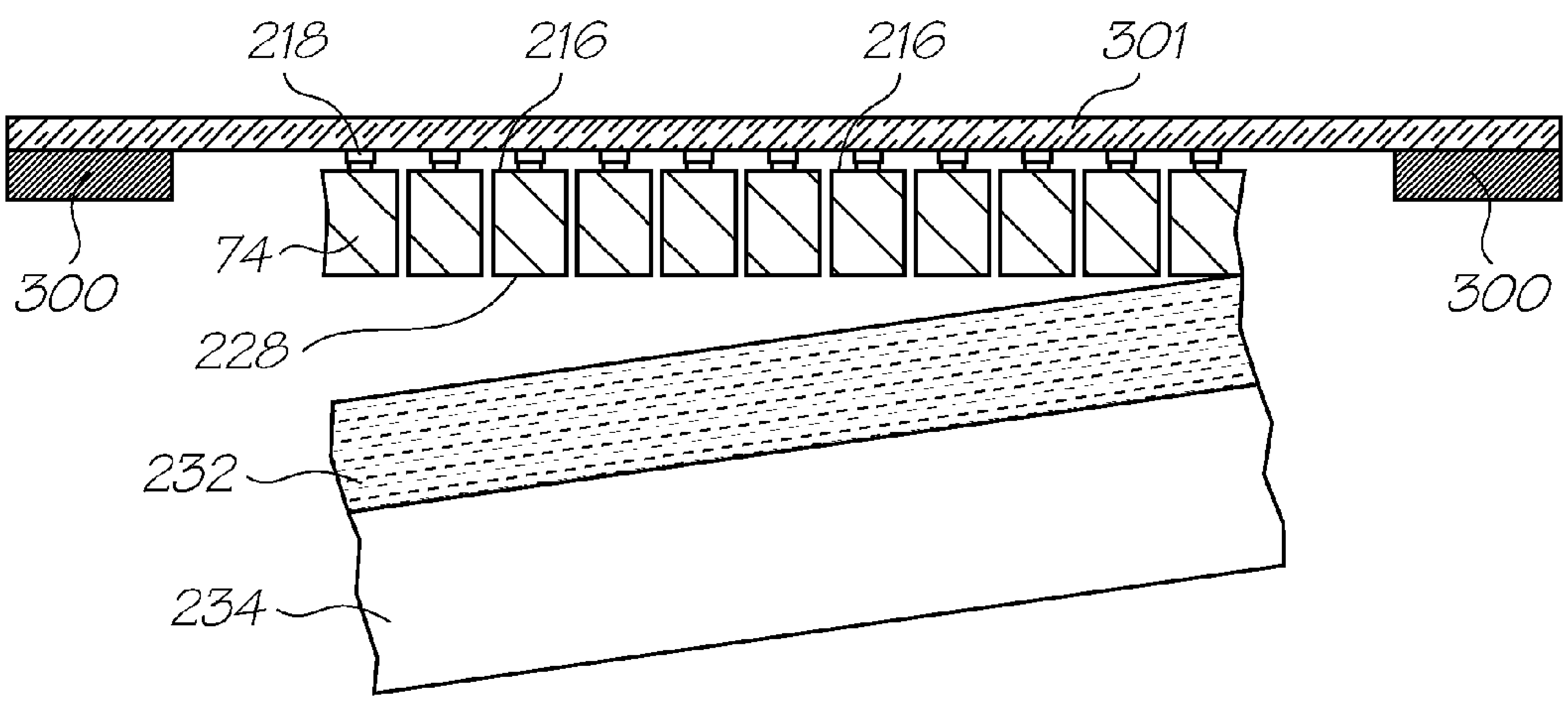
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FIG. 16

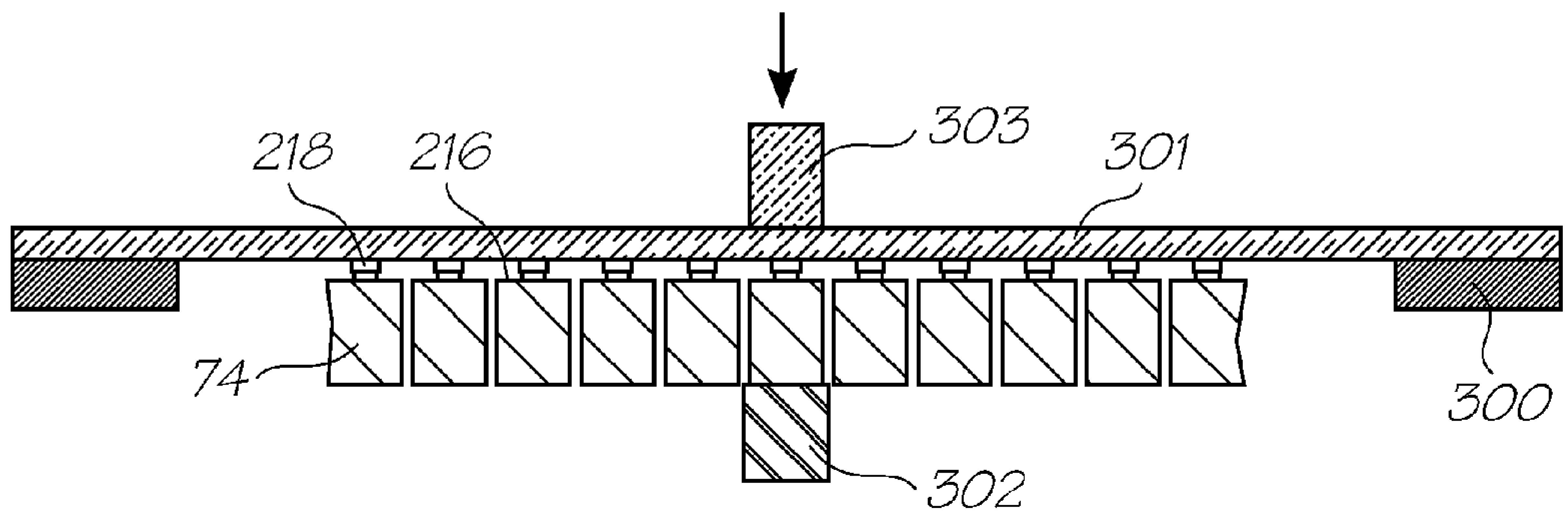

FIG. 17

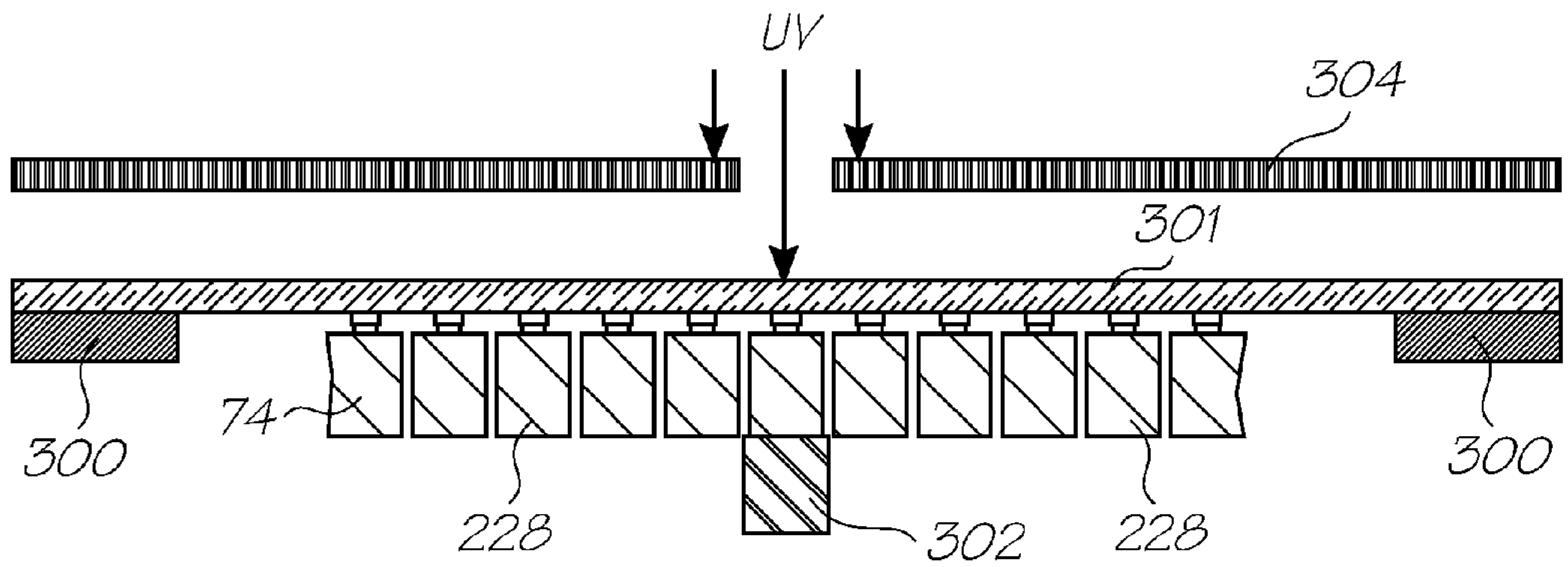

FIG. 18

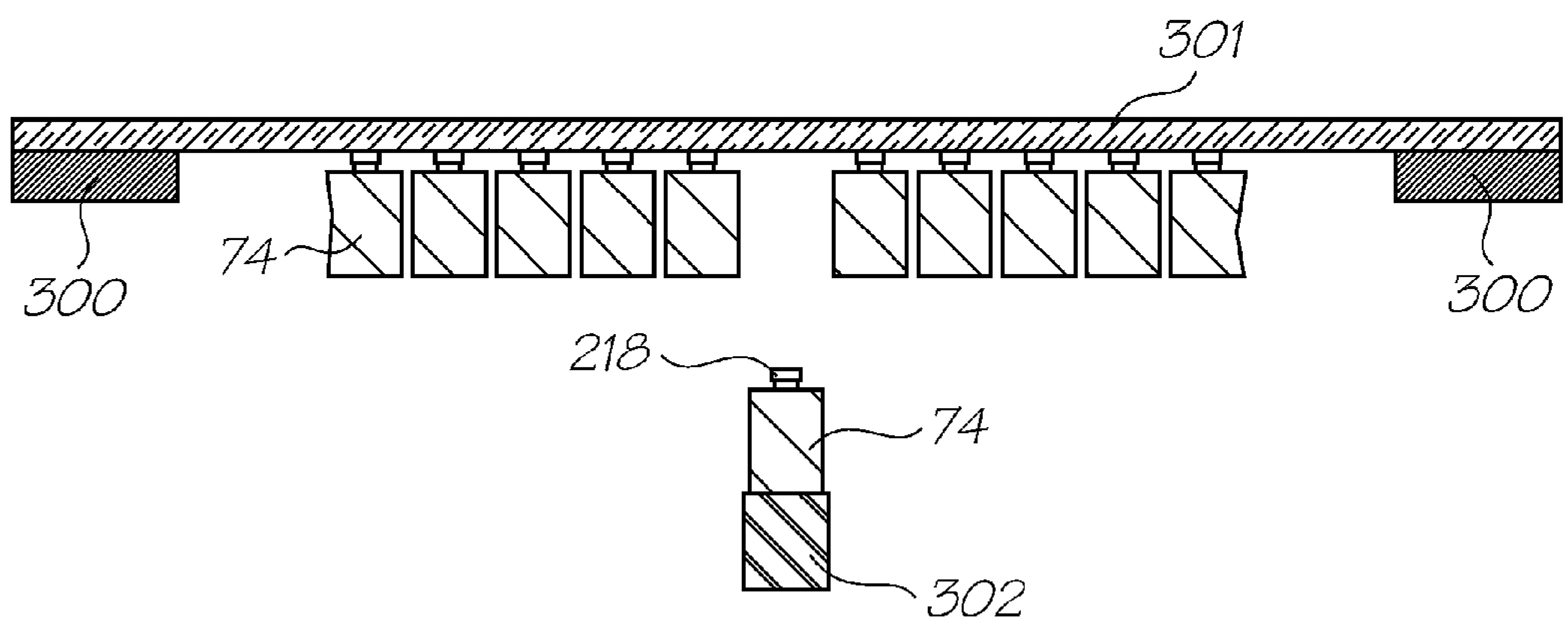

FIG. 19

METHOD OF MOUNTING MEMS INTEGRATED CIRCUITS DIRECTLY FROM WAFER FILM FRAME

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation of U.S. application Ser. No. 12/711,256 filed Feb. 24, 2010, which is a continuation of U.S. application Ser. No. 11/766,052 filed Jun. 20, 2007, now issued as U.S. Pat. No. 7,678,667 all of which are herein incorporated by reference.

FIELD OF THE INVENTION

The present invention relates to the fabrication and bonding of MEMS integrated circuits. It has been developed primarily to facilitate construction of printheads from a plurality of such printhead integrated circuits.

CROSS REFERENCE TO RELATED APPLICATIONS

The following patents or patent applications filed by the applicant or assignee of the present invention are hereby incorporated by cross-reference.

6,405,055	6,628,430	7,136,186	7,286,260	7,145,689
7,130,075	7,081,974	7,177,055	7,209,257	7,161,715
7,154,632	7,158,258	7,148,993	7,075,684	7,564,580
7,241,005	7,108,437	6,915,140	6,999,206	7,136,198
7,092,130	7,249,108	6,566,858	6,331,946	6,246,970
6,442,525	7,346,586	7,685,423	6,374,354	7,246,098
6,816,968	6,757,832	6,334,190	6,745,331	7,249,109
7,197,642	7,093,139	7,509,292	7,685,424	7,743,262
7,210,038	7,401,223	7,702,926	7,716,098	7,757,084
7,747,541	7,657,488	7,170,652	6,967,750	6,995,876
7,099,051	7,453,586	7,193,734	7,773,245	7,468,810
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7,258,417	7,293,853	7,328,968	7,270,395	7,461,916
7,510,264	7,334,864	7,255,419	7,284,819	7,229,148
7,258,416	7,273,263	7,270,393	6,984,017	7,347,526
7,357,477	7,780,261	7,465,015	7,364,255	7,357,476
7,758,148	7,284,820	7,341,328	7,246,875	7,322,669
7,878,618	7,445,311	7,452,052	7,455,383	7,448,724
7,441,864	7,637,588	7,648,222	7,669,958	7,607,755
7,699,433	7,658,463	7,344,226	7,328,976	7,794,613
7,669,967	7,976,132	7,938,974	7,605,009	7,568,787
7,663,784	7,331,651	7,334,870	7,334,875	7,416,283
7,438,386	7,461,921	7,506,958	7,472,981	7,448,722
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7,401,888	7,387,358	7,413,281	7,530,663	7,467,846
7,669,957	7,771,028	7,758,174	7,695,123	7,798,600
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6,247,793	6,264,306	6,241,342	6,247,792	6,264,307
6,254,220	6,234,611	6,302,528	6,283,582	6,239,821
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6,260,953	6,267,469	6,588,882	6,742,873	6,918,655
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6,848,181	6,634,735	6,299,289	6,299,290	6,425,654
6,902,255	6,623,101	6,406,129	6,505,916	6,457,809
6,550,895	6,457,812	7,152,962	6,428,133	7,216,956
7,080,895	7,442,317	7,182,437	7,357,485	7,387,368
7,984,973	7,618,124	7,654,641	7,794,056	7,611,225
7,794,055	7,748,827	7,735,970	7,637,582	7,419,247
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7,455,376	7,841,713	7,877,111	7,874,659	7,735,993
7,991,432	7,284,921	7,407,257	7,470,019	7,645,022
7,392,950	7,843,484	7,360,880	7,517,046	7,236,271
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7,780,288	11/124,172	7,566,182	11/124,182	7,715,036
11/124,181	7,697,159	7,595,904	7,726,764	7,770,995
7,466,993	7,370,932	7,404,616	11/124,187	7,740,347
7,500,268	7,558,962	7,447,908	7,792,298	7,661,813
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7,878,645	7,562,973	7,530,446	7,628,467	7,761,090
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7,697,714	7,654,444	7,831,244	7,499,765	7,894,703
7,756,526	7,844,257	7,558,563	7,953,387	7,856,225
7,945,943	7,747,280	7,742,755	7,738,674	7,864,360
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7,646,503	7,843,595	7,672,664	7,920,896	7,783,323
7,843,596	7,778,666	7,970,435	7,917,171	7,558,599
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7,403,796	7,407,092	7,848,777	7,637,424	7,469,829
7,774,025	7,558,597	7,558,598	6,087,638	6,340,222
6,299,300	6,067,797	6,286,935	6,382,769	6,787,051
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7,510,267	7,465,041	7,857,428	7,465,032	7,401,890
7,401,910	7,470,010	7,735,971	7,431,432	7,465,037
7,445,317	7,549,735	7,597,425	7,661,800	7,712,869
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7,401,894	7,322,676	7,152,959	7,213,906	7,178,901
7,222,938	7,108,353	7,104,629	7,455,392	7,370,939
7,429,095	7,404,621	7,261,401	7,461,919	7,438,388
7,328,972	7,322,673	7,306,324	7,306,325	7,524,021
7,399,071	7,556,360	7,303,261	7,568,786	7,517,049
7,549,727	7,399,053	7,467,849	7,303,930	7,401,405
7,464,466	7,464,465	7,246,886	7,128,400	7,108,355
6,991,322	7,287,836	7,118,197	7,575,298	7,364,269
7,077,493	6,962,402	7,686,429	7,147,308	7,524,034
7,118,198	7,168,790	7,172,270	7,229,155	6,830,318
7,195,342	7,175,261	7,465,035	7,108,356	7,118,202
7,510,269	7,134,744	7,510,270	7,134,743	7,182,439
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7,111,926	7,431,433	7,018,021	7,401,901	7,468,139
7,128,402	7,387,369	7,484,832	7,802,871	7,506,968
7,284,839	7,246,885	7,229,156	7,533,970	7,467,855
7,293,858	7,520,594	7,588,321	7,258,427	7,556,350
7,278,716	7,841,704	7,524,028	7,467,856	7,469,996
7,506,963	7,533,968	7,556,354	7,524,030	7,581,822
7,549,729	7,448,729	7,246,876	7,431,431	7,419,249
7,377,623	7,328,978	7,334,876	7,147,306	7,261,394
7,611,218	7,654,645	7,784,915	7,491,911	7,721,948
7,079,712	6,825,945	7,330,974	6,813,039	6,987,506
7,038,797	6,980,318	6,816,274	7,102,772	7,350,236
6,681,045	6,728,000	7,173,722	7,088,459	7,707,082
7,068,382	7,062,651	6,789,194	6,789,191	6,644,642
6,502,614	6,622,999	6,669,385	6,549,935	6,987,573
6,727,996	6,591,884	6,439,706	6,760,119	7,295,332
6,290,349	6,428,155	6,785,016	6,870,966	6,822,639
6,737,591	7,055,739	7,233,320	6,830,196	6,832,717
6,957,768	7,456,820	7,170,499	7,106,888	7,123,239
7,468,284	7,341,330	7,372,145	7,425,052	7,287,831
7,377,608	7,399,043	7,121,639	7,165,824	7,152,942
7,818,519	7,181,572	7,096,137	7,302,592	7,278,034
7,188,282	7,592,829	7,770,008	7,707,621	7,523,111
7,573,301	7,660,998	7,783,886	7,831,827	7,171,323
7,278,697	7,360,131	7,519,772	7,328,115	7,747,887
7,805,626	7,369,270	6,795,215	7,070,098	7,154,638
6,805,419	6,859,289	6,977,751	6,398,332	6,394,573
6,622,923	6,747,760	6,921,144	7,092,112	7,192,106

-continued

7,457,001	7,173,739	6,986,560	7,008,033	7,551,324
7,222,780	7,270,391	7,525,677	7,388,689	7,398,916
7,571,906	7,654,628	7,611,220	7,556,353	7,195,328
7,182,422	7,866,791	7,841,703	7,374,266	7,427,117
7,448,707	7,281,330	7,328,956	7,735,944	7,188,928
7,093,989	7,377,609	7,600,843	10/854,498	7,390,071
7,549,715	7,252,353	7,607,757	7,267,417	7,517,036
7,275,805	7,314,261	7,281,777	7,290,852	7,484,831
7,758,143	7,832,842	7,549,718	7,866,778	7,631,190
7,557,941	7,757,086	7,266,661	7,243,193	7,163,345
7,322,666	7,566,111	7,434,910	7,837,284	7,543,808
7,946,674	7,819,494	7,938,500	7,845,747	7,425,048
11/544,766	7,780,256	7,384,128	7,604,321	7,722,163
7,681,970	7,425,047	7,413,288	7,465,033	7,452,055
7,470,002	7,722,161	7,475,963	7,448,735	7,465,042
7,448,739	7,438,399	7,467,853	7,461,922	7,465,020
7,722,185	7,461,910	7,270,494	7,632,032	7,475,961
7,547,088	7,611,239	7,735,955	7,758,038	7,681,876
7,780,161	7,703,903	7,703,900	7,703,901	7,722,170
7,857,441	7,784,925	7,794,068	7,794,038	7,448,734
7,425,050	7,364,263	7,201,468	7,360,868	7,234,802
7,303,255	7,287,846	7,156,511	7,258,432	7,097,291
7,645,025	7,083,273	7,367,647	7,374,355	7,441,880
7,547,092	7,513,598	7,198,352	7,364,264	7,303,251
7,201,470	7,121,655	7,293,861	7,232,208	7,328,985
7,344,232	7,083,272	7,311,387	7,303,258	7,824,002
7,517,050	7,708,391	7,621,620	7,669,961	7,331,663
7,360,861	7,328,973	7,427,121	7,407,262	7,303,252
7,249,822	7,537,309	7,311,382	7,360,860	7,364,257
7,390,075	7,350,896	7,429,096	7,384,135	7,331,660
7,416,287	7,488,052	7,322,684	7,322,685	7,311,381
7,270,405	7,303,268	7,470,007	7,399,072	7,393,076
7,681,967	7,588,301	7,249,833	7,547,098	7,524,016
7,490,927	7,331,661	7,524,043	7,300,140	7,357,492
7,357,493	7,566,106	7,380,902	7,284,816	7,284,845
7,255,430	7,390,080	7,328,984	7,350,913	7,322,671
7,380,910	7,431,424	7,470,006	7,585,054	7,347,534
7,441,865	7,469,989	7,367,650	7,469,990	7,441,882
7,556,364	7,357,496	7,467,863	7,431,440	7,431,443
7,527,353	7,524,023	7,513,603	7,467,852	7,465,045
11/688,863	7,837,297	7,475,976	7,364,265	11/688,867
7,758,177	7,780,278	11/688,871	7,819,507	7,654,640
7,721,441	7,645,034	7,637,602	7,645,033	7,661,803
7,841,708	7,771,029	11/677,050	7,658,482	7,306,320
7,111,935	7,562,971	7,735,982	7,604,322	7,261,482
7,002,664	7,088,420	7,470,014	7,470,020	7,540,601
7,654,761	7,377,635	7,686,446	7,237,888	7,168,654
7,201,272	6,991,098	7,217,051	6,944,970	7,108,434
7,210,407	7,186,042	6,920,704	7,217,049	7,607,756
7,147,102	7,287,828	7,249,838	7,431,446	7,611,237
7,261,477	7,225,739	7,712,886	7,665,836	7,419,053
7,191,978	7,524,046	7,163,287	7,258,415	7,322,677
7,258,424	7,484,841	7,195,412	7,207,670	7,270,401
7,220,072	7,588,381	7,726,785	7,578,387	7,575,316
7,384,206	7,628,557	7,470,074	7,425,063	7,429,104
7,556,446	7,367,267	7,901,065	7,794,051	7,695,204
7,322,761	7,735,994	7,079,292		

BACKGROUND OF THE INVENTION

The present Applicant has described previously how a pagewidth inkjet printhead may be constructed from a plurality of abutting printhead integrated circuits (also known as printhead ICs, printhead chips and printhead dies). As described extensively in, for example, Applicant's U.S. application Ser. No. 11/014,732 filed on Dec. 12, 2004 (the contents of which is herein incorporated by reference), a pagewidth printhead usually comprises a plurality of abutting printhead ICs attached to a liquid crystal polymer (LCP) ink manifold via an adhesive intermediary layer, which is sandwiched between the LCP ink manifold and the printhead ICs. The adhesive intermediary layer is typically a laser-drilled epoxy-coated polymer film.

The construction of such printheads presents a number of design challenges. Firstly, the printhead ICs must be mounted with high precision on the polymer film so that laser-drilled holes in the film are aligned with backside ink supply channels in the printhead ICs. Secondly, the MEMS fabrication process for the printhead ICs should preferably present the ICs in such a way that facilitates bonding onto the intermediary layer.

Hitherto, the Applicant has described how backside MEMS processing of a printhead wafer may be performed to provide individual printhead ICs (see, for example, U.S. Pat. No. 6,846,692, the contents of which is incorporated herein by reference). During backside MEMS processing, the backside of the wafer is ground to a desired wafer thickness (typically 100 to 300 microns) and ink supply channels are etched from a backside of the wafer so as to form a fluidic connection between the backside, which receives ink, and nozzle assemblies on a frontside of the wafer. In addition, backside MEMS processing defines dicing streets in the wafer so that the wafer can be separated into the individual printhead ICs. Finally, any photoresist in the wafer is ashed off using an oxidative plasma. The exact ordering of backside MEMS processing steps may be varied, although backside MEMS processing is typically performed after completion of all frontside MEMS fabrication steps, in which the nozzle assemblies are constructed on the frontside of the wafer.

In the process described in U.S. Pat. No. 6,846,692, the individual printhead ICs end up mounted, via their backsides, to a handling means. The handling means may be a glass handle wafer, with the printhead ICs attached thereto via a releasable adhesive tape e.g. UV-release tape or thermal-release tape. Alternatively, the handling means may be a wafer film frame, with the printhead ICs being attached to a dicing tape supported by the wafer film frame. Wafer film frame arrangements will be well known to the person skilled in the art.

The printhead ICs may be picked off individually from the handling means (for, example, using a robot) and either packaged or bonded directly to an intermediary substrate to construct a printhead. U.S. Pat. No. 6,946,692 describes how a vacuum pick-up may be used in combination with a reciprocating x-y wafer stage and a UV lamp/mask to remove individual printhead ICs from a glass handle wafer.

However, a problem with the process described in U.S. Pat. No. 6,846,692 is that the individual printhead ICs must be removed from the handling means and then aligned and bonded with high accuracy to the intermediary substrate. Whilst robot handling of the ICs helps to improve alignment accuracies, there are inevitable alignment losses in such a process.

It would be desirable to provide a process for removing MEMS devices, such as printhead ICs, from a handling means, which facilitates alignment of the devices when bonded to a further substrate, such the intermediary substrate described above.

It would be further desirable to provide a process for printhead construction, which facilitates the use of alternative non-polymeric intermediary substrates. Polymeric adhesive layers are inexpensive and convenient to handle, but suffer from comparatively high thermal expansion relative to the silicon printhead ICs and the LCP ink supply manifold. A comparatively high coefficient of thermal expansion for the intermediary substrate exacerbates alignment problems during construction and may even lead to loss of alignment over the duration of the printhead lifetime.

SUMMARY OF THE INVENTION

In a first aspect the present invention provides a method of bonding an integrated circuit to a substrate, said integrated circuit being one of a plurality of integrated circuits each having a respective frontside releasably attached to a film frame tape supported by a wafer film frame, said method comprising the steps of:

(a) positioning a substrate at a backside of said integrated circuit;

(c) positioning a bonding tool on a zone of said film frame tape, said zone being aligned with said integrated circuit; and

(c) applying a bonding force from said bonding tool, through said film frame tape and said integrated circuit, onto said substrate,

thereby bonding said backside of said integrated circuit to said substrate.

In a further aspect there is provided a method, further comprising the step of:

removing said bonding tool from said tape.

Optionally, said film frame tape is a UV-release tape.

In a further aspect there is provided a method, further comprising the step of:

exposing said zone of said film frame tape to UV radiation and releasing said bonded integrated circuit from said tape.

Optionally, said integrated circuit is a MEMS integrated circuit.

Optionally, said integrated circuit is a printhead integrated circuit.

Optionally, steps (a) to (c) are repeated so as to construct a printhead on said substrate, said printhead comprising a plurality of abutting printhead integrated circuits.

Optionally, said substrate has a plurality of ink supply holes defined therein, wherein one or more of said holes are aligned with ink supply channels defined in the backside of said printhead integrated circuit.

Optionally, said substrate is an intermediary substrate for attachment of said printhead integrated circuit to an ink supply manifold.

Optionally, said intermediary substrate is an adhesive polymer film.

Optionally, said intermediary substrate is a rigid member having a coefficient of thermal expansion within about 20% of the coefficient of thermal expansion of the printhead integrated circuit and/or the ink supply manifold.

Optionally, said intermediary substrate is a glass member.

Optionally, a backside of each of the plurality of integrated circuits is pre-treated for bonding to said intermediary substrate.

Optionally, said backside comprises an oxide layer.

Optionally, said oxide layer is pre-treated with liquid ammonia.

In a second aspect the present invention provides a method of constructing a printhead using a plurality of printhead integrated circuits, each of said printhead integrated circuits having a respective frontside releasably attached to a film frame tape supported by a wafer film frame, said method comprising the steps of:

(a) positioning a substrate at a backside of one of said printhead integrated circuits;

(c) positioning a bonding tool on a zone of said film frame tape, said zone being aligned with said printhead integrated circuit;

(c) applying a bonding force from said bonding tool, through said film frame tape and said printhead integrated circuit, onto said substrate, thereby bonding said backside of said printhead integrated circuit to said substrate;

(d) repeating steps (a) to (c) so as to construct a printhead on said substrate, wherein said printhead comprises a predetermined number of abutting printhead integrated circuits.

Optionally, said substrate comprises a plurality of ink supply holes defined therein, each of said holes being aligned with an ink supply channel defined in the backside of said printhead.

Optionally, said substrate is a glass member.

In a further aspect there is provided a method, further comprising the step of:

bonding said substrate to an ink supply manifold such that said substrate is sandwiched between said printhead and said ink supply manifold.

Optionally, said printhead is a pagewidth inkjet printhead.

BRIEF DESCRIPTION OF THE DRAWINGS

Optional embodiments of the present invention will now be described by way of example only with reference to the accompanying drawings, in which:

FIG. **1** is a front perspective view of a printhead assembly;

FIG. **2** is an exploded front perspective view the printhead assembly shown in FIG. **1**;

FIG. **3** is an exploded rear perspective view the printhead assembly shown in FIG. **1**;

FIG. **4** is a side-sectional view of the printhead assembly shown in FIG. **1**;

FIG. **5** shows a wafer assembly having a plurality of nozzles protected by a protective layer;

FIG. **6** shows the wafer assembly of FIG. **5** after attachment of an adhesive tape to the protective layer;

FIG. **7** shows the wafer assembly of FIG. **6** after attachment of a handle wafer to the adhesive tape;

FIG. **8** shows the wafer assembly of FIG. **7** flipped for backside processing;

FIG. **9** shows the wafer assembly of FIG. **8** after backside processing, which includes defining dicing streets in the wafer;

FIG. **10** shows the wafer assembly of FIG. **9** after attachment of a backside handle wafer using an adhesive tape;

FIG. **11** shows the wafer assembly of FIG. **10** after releasing the frontside handle wafer and tape;

FIG. **12** shows the wafer assembly of FIG. **11** flipped;

FIG. **13** shows the wafer assembly of FIG. **12** after ashing the protective layer;

FIG. **14** shows the wafer assembly of FIG. **13** with individual chips being removed;

FIG. **15** shows the wafer assembly of FIG. **13** attached mounted to a wafer film frame;

FIG. **16** shows the assembly of FIG. **15** with the second handle wafer and tape partially removed;

FIG. **17** shows a printhead integrated circuit being bonded to an intermediary substrate;

FIG. **18** shows a bonded printhead integrated circuit being detached from a film frame tape; and

FIG. **19** shows the bonded printhead integrated circuit separated from the wafer film frame.

DESCRIPTION OF OPTIONAL EMBODIMENTS

Printhead Assembly

A constructed printhead assembly **22** for a pagewidth printer (not shown) is shown in FIGS. **1** to **4**. The printhead assembly **22** generally comprises an elongate upper member **62** having a plurality of projecting U-shaped clips **63**. These clips **63** are captured by lugs (not shown) formed in a main body (not shown) of the printer to secure the printhead assembly **22** thereto.

The upper element **62** has a plurality of feed tubes **64** that receive ink from ink reservoirs (not shown) in the printer. The feed tubes **64** may be provided with an outer coating to guard against ink leakage.

The upper member **62** is made from a liquid crystal polymer (LCP) which offers a number of advantages. It can be molded so that its coefficient of thermal expansion (CTE) is similar to that of silicon. It will be appreciated that any significant difference in the CTE's of the printhead integrated circuit **74** (discussed below) and the underlying moldings can cause the entire structure to bow. LCP also has a relatively high stiffness with a modulus that is typically 5 times that of 'normal plastics' such as polycarbonates, styrene, nylon, PET and polypropylene.

As best shown in FIG. **2**, upper member **62** has an open channel configuration for receiving a lower member **65**, which is bonded thereto, via an adhesive film **66**. The lower member **65** is also made from an LCP and has a plurality of ink channels **67** formed along its length. Each of the ink channels **67** receives ink from one of the feed tubes **64**, and distributes the ink along the length of the printhead assembly **22**. The channels are 1 mm wide and separated by 0.75 mm thick walls.

In the embodiment shown, the lower member **65** has five channels **67** extending along its length. Each channel **67** receives ink from only one of the five feed tubes **64**.

In the bottom of each channel **67** are a series of equi-spaced holes **69** (best seen in FIG. **3**) to give five rows of holes **69** in the bottom surface of the lower member **65**. The middle row of holes **69** extends along the centre-line of the lower member **65**, directly above the printhead IC **74**.

Referring to FIG. **4**, the printhead ICs **74** are mounted to the underside of the lower member **65** by a polymer sealing film **71**. This film may be a thermoplastic film such as a PET or polysulphone film, or it may be in the form of a thermoset film, such as those manufactured by AL technologies and Rogers Corporation. The polymer sealing film **71** is a laminate with adhesive layers on both sides of a central web, and laminated onto the underside of the lower member **65**. As shown in FIG. **3**, a plurality of holes **72** are laser drilled through the adhesive film **71** to coincide with the centrally disposed ink delivery points (the middle row of holes **69** and the ends of the conduits **70**) for fluid communication between the printhead ICs **74** and the channels **67**.

The printhead ICs **74** are arranged to extend horizontally across the width of the printhead assembly **22**. To achieve this, individual printhead ICs **74** are linked together in abutting arrangement to form a printhead **56** across the surface of the adhesive layer **71**, as shown in FIGS. **2** and **3**.

As described in the Applicant's earlier U.S. application Ser. No. 11/014,732 filed on Dec. 12, 2004, the printhead ICs **74** may be attached to the polymer sealing film **71** by heating the ICs above the melting point of the adhesive layer and then pressing them into the sealing film **71**. Alternatively, the adhesive layer under each IC may be melted with a laser before pressing them into the film. Another option is to heat both the IC (not above the adhesive melting point) and the adhesive layer, before pressing the IC into the film **71**. As alluded to above, this method of printhead fabrication has inherent alignment problems.

Following attachment and alignment of each of the printhead ICs **74** to the surface of the polymer sealing film **71**, a flex PCB **79** (see FIG. **4**) is attached along an edge of the ICs **74** so that control signals and power can be supplied to the bond pads on the ICs and control and operate inkjet nozzles. As shown more clearly in FIG. **1**, the flex PCB **79** folds around the printhead assembly **22**.

The flex PCB **79** may also have a plurality of decoupling capacitors **81** arranged along its length for controlling the power and data signals received. As best shown in FIG. **2**, the flex PCB **79** has a plurality of electrical contacts **180** formed along its length for receiving power and/or data signals from control circuitry of the printer. A plurality of holes **80** are also formed along the distal edge of the flex PCB **79** which provide a means for attaching the flex PCB to complementary connectors in the printer.

As shown in FIG. **4**, a media shield **82** protects the printhead ICs **74** from damage which may occur due to contact with the passing media. The media shield **82** is attached to the upper member **62** upstream of the printhead ICs **74** via an appropriate clip-lock arrangement or via an adhesive. When attached in this manner, the printhead ICs **74** sit below the surface of the media shield **82**, out of the path of the passing media.

Backside MEMS Processing Described in U.S. Pat. No. 6,846,692

FIGS. **5** to **14** outline typical backside MEMS processing steps, as described in U.S. Pat. No. 6,846,692 (the contents of which is herein incorporated by reference), for fabrication of the printhead ICs **74**. In an initial step, illustrated at **210** in FIG. **5**, a silicon wafer **212** is provided having a frontside **216** on which is formed a plurality of MEMS nozzle assemblies **218** in a MEMS layer **214**. The MEMS nozzle assemblies **218** typically comprise a sacrificial material, which fills nozzle chambers.

A protective layer **220** is interposed between the nozzle assemblies **218**. This protective layer **220** is typically a relatively thick layer (e.g. 1 to 10 microns) of sacrificial material, such as photoresist, which is spun onto the frontside **216** after fabrication of the MEMS nozzle assemblies **218**. The photoresist is UV cured and/or hardbaked to provide a rigid and durable protective coating that is suitable for attachment to a glass handle wafer.

A first holding means, in the form of an adhesive tape **222**, is bonded to the MEMS layer **14** as illustrated in FIG. **6**. The tape **222** is bonded to the layer **214** by means of a curable adhesive. The adhesive is curable in the sense that it loses its adhesive properties or "tackiness" when exposed to ultraviolet (UV) light or heat. The tape **222** described in the specific embodiment herein is a UV-release tape, although it will be appreciated that thermal-release tapes are equally suitable for use as the first holding means.

As shown in FIG. **7**, a first handle wafer **224**, in the form of a glass, quartz, alumina or other handle wafer, is secured to the tape **222**.

A laminate **226**, comprising the silicon wafer **212** with MEMS layer **214**, the tape **222** and the glass wafer **224** is then turned over to expose an opposed backside **228** of the wafer.

The backside **228** of the silicon wafer **212** is then thinned by backgrinding a surface **228.1**, as illustrated in FIG. **8**. Wafer thinning may include plasma thinning to remove any surface cracks or indentations resulting from backgrinding.

Then, as shown in FIG. **9**, the silicon wafer **212** is deep silicon etched through the wafer from the backside **228** to dice the wafer **212** and form individual integrated circuits **74**. In FIG. **9**, each IC **74** has only one MEMS nozzle assembly **218** associated therewith, although it will be appreciated that each IC typically contains an array (e.g. greater than 2000) nozzle assemblies arranged in rows.

At the same time as etching dicing streets from the backside **228** of the wafer **212**, ink supply channels may also be etched so as to provide a fluidic connection to each nozzle assembly **218**.

Following backside etching, and as shown in FIG. **10**, a second holding means in the form of a second adhesive tape **232** (e.g. UV-release tape or thermal-release tape) is bonded to the backside surface **228.1** of the wafer **212**, and a second handle wafer **234** is bonded to the tape **232**.

After attachment of the second handle wafer **234**, the first tape **222** and the glass wafer **224** are removed, as illustrated schematically by arrow **236** in FIG. **11**. The tape **222** may be removed by exposing it to UV light which is projected on to the tape **222** through the glass layer **224** as illustrated by arrows **238**. It will be appreciated that the glass wafer **224** is transparent to the UV light. In contrast, the silicon wafer **212** is opaque to the UV light so that the tape **232** on the other side of the wafer **212** is not affected by the UV light when the tape **222** is exposed to the UV light.

Referring to FIG. **12**, once the tape **222** and glass wafer **224** have been removed, a new laminate **240**, comprising the silicon wafer with MEMS layer **214**, the second tape **232** and the glass wafer **234** is turned over to expose the protective layer **220**.

Referring to FIG. **13**, the protective layer **220** is then removed by ashing in an oxygen plasma. This releases the MEMS nozzle assemblies **218**, and completes the separation of the ICs **74**. At the same time as removing the protective layer **220**, any other exposed sacrificial material, which remained from frontside MEMS fabrication, is also removed.

The laminate **240** is then placed on an xy wafer stage (not shown) which is reciprocated, as illustrated by arrow **244** in FIG. **14**. Each IC **74**, when it is desired to remove it, is exposed to UV light as indicated by arrows **246** through a mask **250**. This cures the adhesive of the tape **232** locally beneath one particular IC **74** at a time, to enable that IC to be removed from the tape **232** by means of a transporting means which may include a vacuum pickup **248**. The printhead ICs **74** can then be packaged and/or formed into a printhead by butting a plurality of ICs together.

Alternative Backside MEMS Processing and Printhead Construction

A shortcoming of the backside MEMS process described above is that the printhead ICs **74** must be individually removed from the second handle wafer **234** and then assembled into the printhead **56** by attaching them to an intermediary substrate, such as the adhesive film **71**. This process has inherent alignment difficulties.

FIGS. **15** to **19** show an alternative sequence of backside MEMS processing steps, which avoids picking ICs **74** individually from the second handle wafer **234**, as shown in FIG. **14**. Instead the ICs **74** are bonded directly onto an intermediary substrate **302** from a wafer film frame **300**, as will be described in more detail below.

Starting from the assembly **240** shown in FIG. **13**, the array of printhead ICs **74** attached to the second handle wafer **234** is mounted to a wafer film frame **300**, as shown in FIG. **15**. The frontside **216** of each printhead IC **74** is attached to a film frame tape **301** supported by the wafer film frame **300**. Whilst the size of the MEMS devices **218** is shown exaggerated in FIG. **15**, it will be appreciated that the printhead ICs **74** have a substantially planar frontside **216** which bonds to the film frame tape **301**.

It is important that the first tape **222** and second tape **232** are complementary with the film frame tape **301** supported by the wafer film frame **300**. Accordingly, in this embodiment it is preferred that the first tape **222** and second tape **232** are thermal-release tapes (e.g. 150° C. thermal release tape and 170° C. thermal release tape), and the film frame tape **301** is a UV-release tape. Thus, the array of printhead ICs **74** can be mounted to the film frame tape **301** and then the second handle wafer **234** with second tape **232** removed from the array by heating.

Referring to FIG. **16**, there is shown the second handle wafer **234** (together with second tape **232**) being removed from the backside **228** of the array of ICs **74**. This may be achieved by simply heating the thermal-release tape **232**. After this step, the printhead ICs **74** are mounted via their frontsides **216** to the film frame tape **301**. The backsides **228** of the printhead ICs **74**, which will be attached to the LCP member **65**, are exposed and ready for bonding.

After removal of the second handle wafer **234** and tape **232**, the exposed backsides **228** of the ICs may be treated for subsequent bonding. For example, the backsides **228** may be treated for bonding using the proprietary Zibond™ bonding process, developed by Ziptronix, Inc. This process typically requires an oxide surface to be treated with liquid ammonia, which prepares the surface for bonding to a range of substrates. The backsides **228** of the ICs **74** may be coated with a layer of oxide at an earlier stage of backside MEMS processing (for example, at the stage shown in FIG. **8**—that is, prior to etching backside dicing streets and ink supply channels). Ammonia treatment of this backside oxide layer may then be performed with the ICs **74** mounted on the wafer film frame **300**. The present invention is particularly suited for the Zibond™ bonding process, because there is minimal handling of the ICs **74** between backside treatment and subsequent bonding.

Alternatively, the backsides **228** of the ICs **74** may be left untreated and bonded to an intermediary substrate, such as the adhesive film **71**, using more conventional adhesive bonding methods.

The principal advantages of the present invention are realized by the sequence of steps represented by FIGS. **17** to **19**. Instead of removing the ICs **74** from the wafer film frame **300**, the backsides **228** are bonded directly to an intermediary substrate **302**, whilst still attached to the film frame tape **301**. A bonding tool **303** may be employed to select and bond an individual IC **74** onto a predetermined position of the intermediary substrate **302**, as shown in FIG. **17**. The use of the bonding tool **303** in combination with the wafer film frame **300** ensures high-precision bonding of individual printhead ICs **74** to the intermediary substrate **302**.

The intermediary substrate **302** may be the laser-drilled adhesive film **71** described earlier. Alternatively, the intermediary substrate **302** may be a rigid, glass member, which takes the place of the adhesive film **71** in bonding the printhead ICs **74** to the LCP member **65**. A glass member is advantageous, because it has a similar coefficient of thermal expansion to the LCP member **65** and the printhead ICs **74**. The skilled person will appreciate that the glass member may be pre-etched with ink supply holes corresponding to the laser-drilled holes **72** of the polymer film **71**.

Hence, it will be appreciated that the present invention improves alignment of the printhead ICs **74** with the intermediary substrate **302**. Alignment is improved firstly by performing the bonding step with the printhead ICs **74** still mounted on the wafer film frame **300**. Secondly, the present invention facilitates the use of intermediary substrates **302** other than the polymeric adhesive film **71** described earlier. In avoiding the use of the polymeric adhesive film **71**, alignment errors resulting from differential thermal expansion are further minimized.

Once the printhead IC **74** is bonded to the intermediary substrate **302**, the bonding tool is removed and the bonded IC **74** detached from the film frame tape **301**. As shown in FIG. **18**, this may achieved by selectively UV-curing a zone of the tape **301**. A suitable mask **304** may be employed for selective UV-curing.

Finally, as shown in FIG. **19**, the intermediary substrate **302** with the IC **74** bonded thereto is separated fully from the wafer film frame **300**. The bonding process illustrated in FIGS. **17** to **19** may be repeated along the length of the intermediary substrate **302** so as to build up the printhead **56** from a plurality of abutting printhead ICs **74**.

Once the printhead **56** is fully constructed, an opposite face of the intermediary substrate **302** is attached to the LCP member **65**, as described above, to form the printhead assembly **22**.

It will be appreciated by ordinary workers in this field that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

The invention claimed is:

1. A method of mounting a MEMS integrated circuit on a substrate, said method comprising the steps of:

(a) providing a film frame tape supported by a wafer film frame, said film frame tape having a plurality of MEMS integrated circuits releasably attached via respective frontsides to said film frame tape, wherein a backside of each MEMS integrated circuit has a surface oxide layer;

(b) treating the surface oxide layer with liquid ammonia;

(c) positioning a substrate at the backside of one of said MEMS integrated circuits;

(d) positioning a bonding tool on a zone of said film frame tape, said zone being aligned with said MEMS integrated circuit; and

(e) applying a bonding force from said bonding tool, through said film frame tape and said MEMS integrated circuit, onto said substrate, thereby bonding said backside of said MEMS integrated circuit to said substrate.

2. The method of claim **1**, wherein said MEMS integrated circuit is a printhead integrated circuit.

3. The method of claim **2**, further comprising:

repeating steps (c) to (e) so as to construct a printhead on said substrate, wherein said printhead comprises a predetermined number of abutting printhead integrated circuits.

4. The method of claim **3**, wherein said substrate has a plurality of ink supply holes defined therein, each of said holes being aligned with an ink supply channel defined in the backside of said printhead.

5. The method of claim **4**, wherein said substrate is comprised of glass.

6. The method of claim **4**, further comprising the step of:

bonding said substrate to an ink supply manifold such that said substrate is sandwiched between said printhead and said ink supply manifold.

7. The method of claim **3**, wherein said printhead is a pagewidth inkjet printhead.

* * * * *